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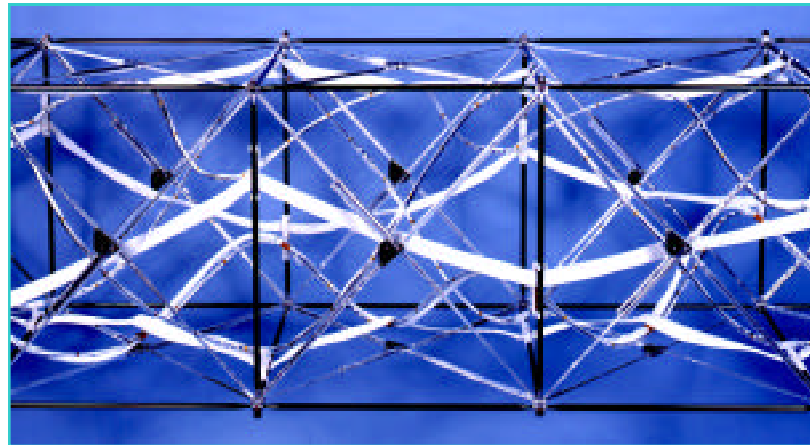
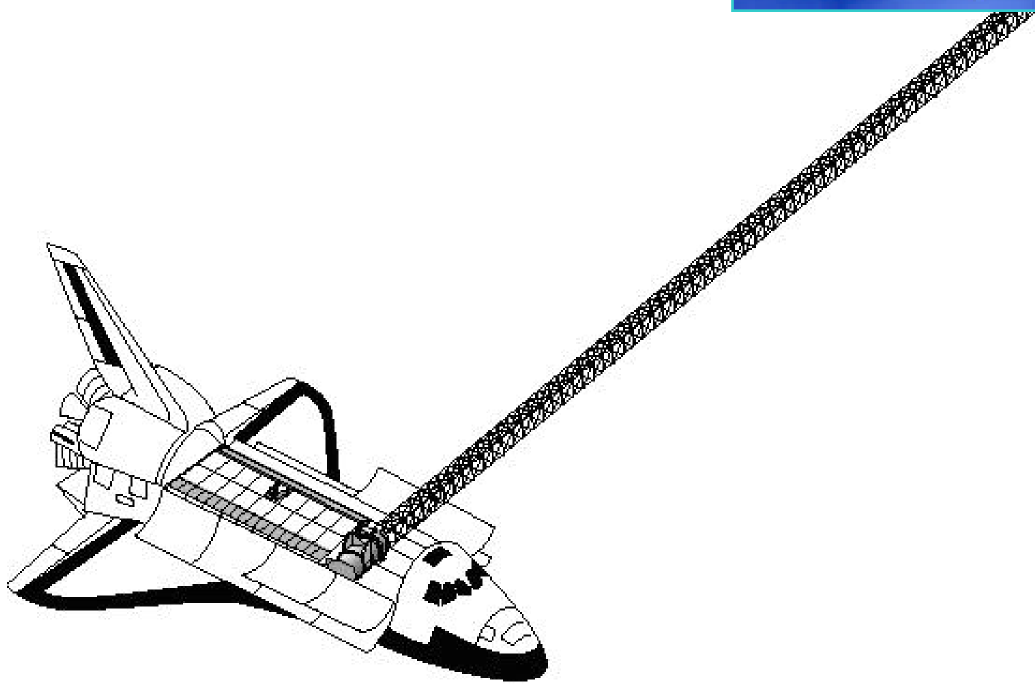


-Bay

Hysteresis Testing



Dave Gross
June 24^{th}

1999 Microdynamics Workshop

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A series of simple tests have been performed on a spare bay of the Able Deployable Articulated Mast (ADAM) built for the Shuttle Radar Topography Mission (SRTM). The objectives of the tests were as follows:

- To enhance the knowledge and understanding of the ADAM's non-linear behavior;
- To assist in developing a non-linear computer model of the ADAM;
- To provide insight into design improvements for the ADAM and other precision structures;
- To assist in developing performance verification techniques for future ADAM hardware systems.

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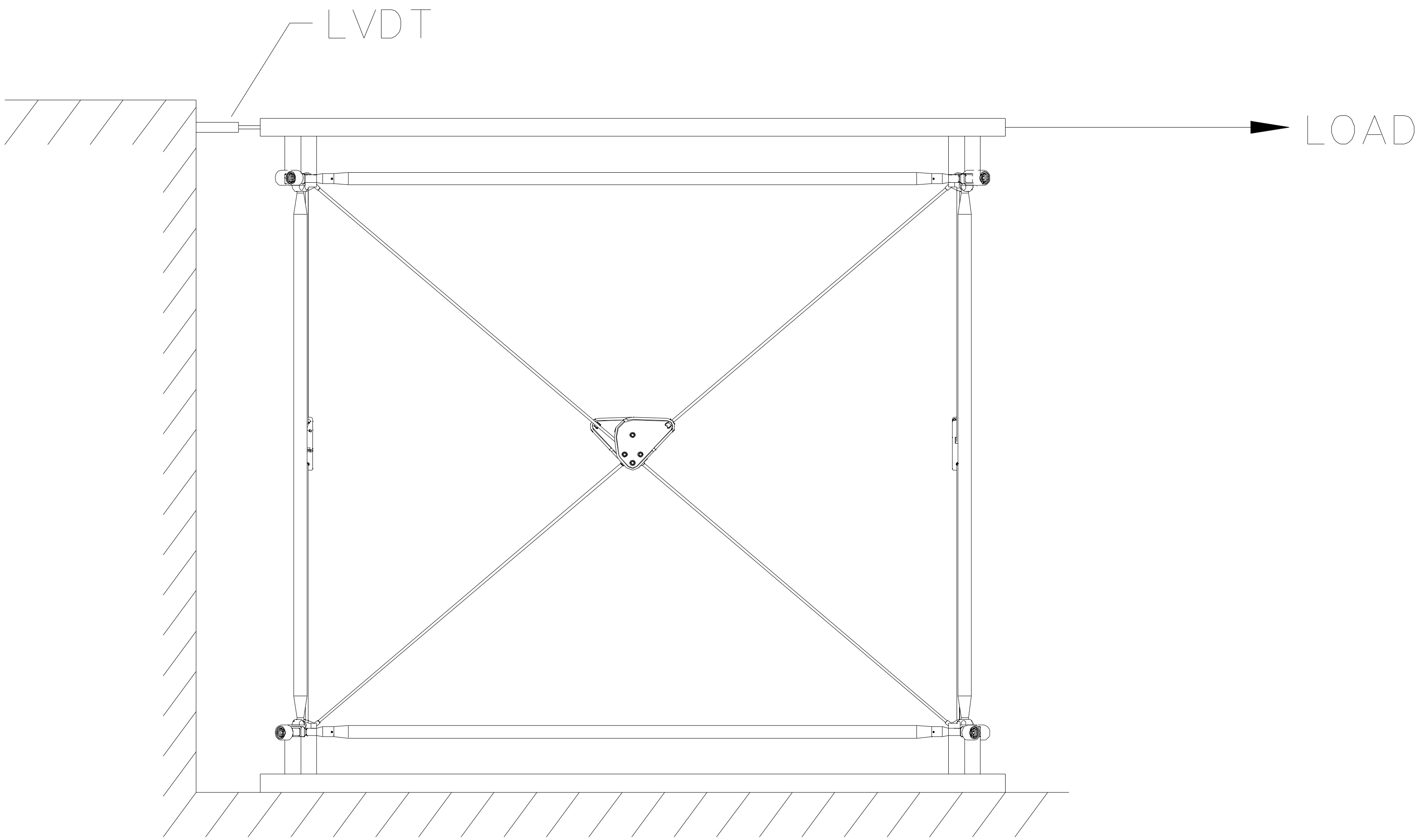
TEST SET-UP SCHEMATIC



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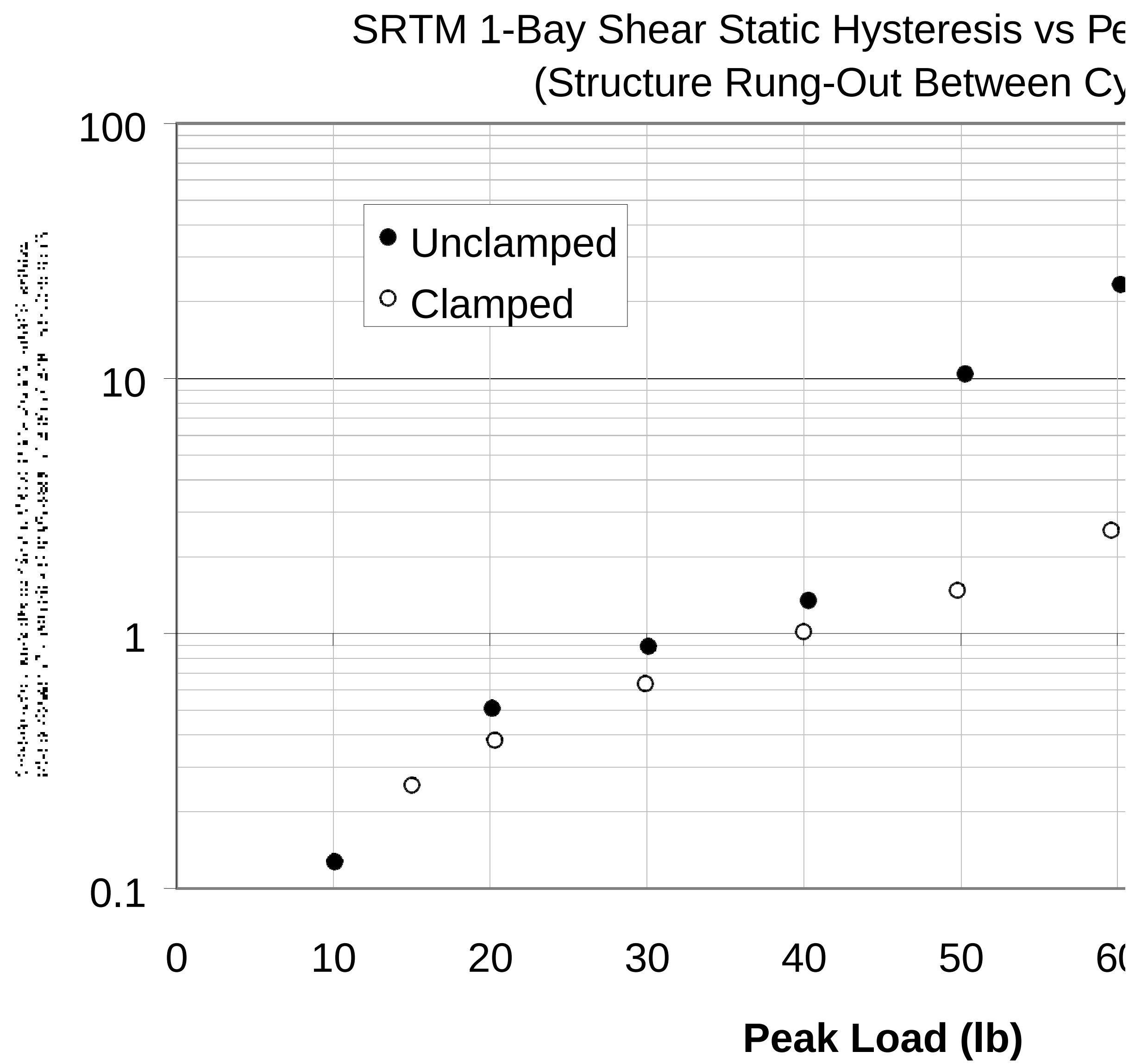

Figure 1

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SRTM 1-Bay Cumulative Shear Displacement and Peak Load vs Load
(Structure Rung-Out Between Cycles) (Diagonal Latches Clamped) (8 Additio

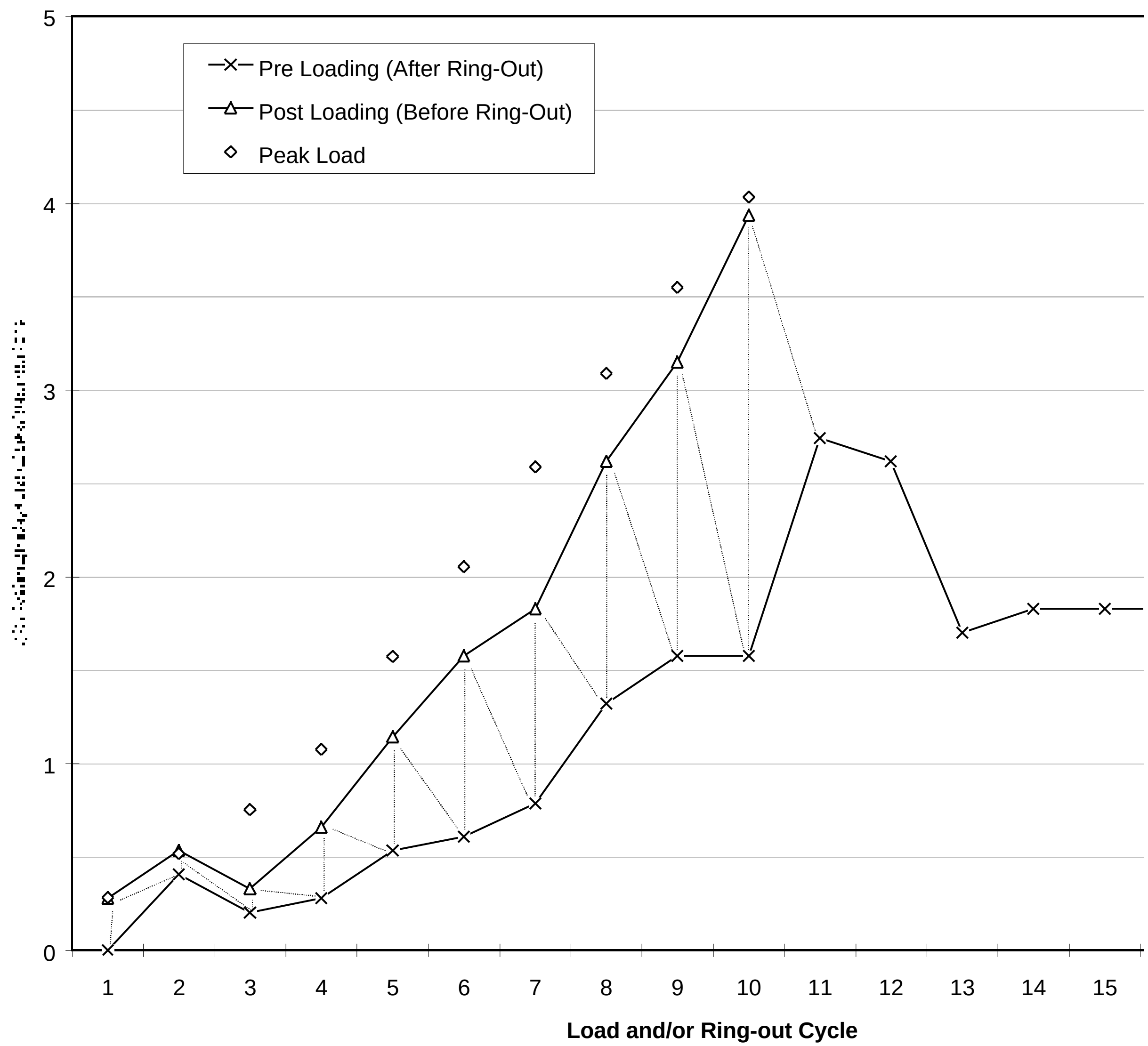

Figure 2

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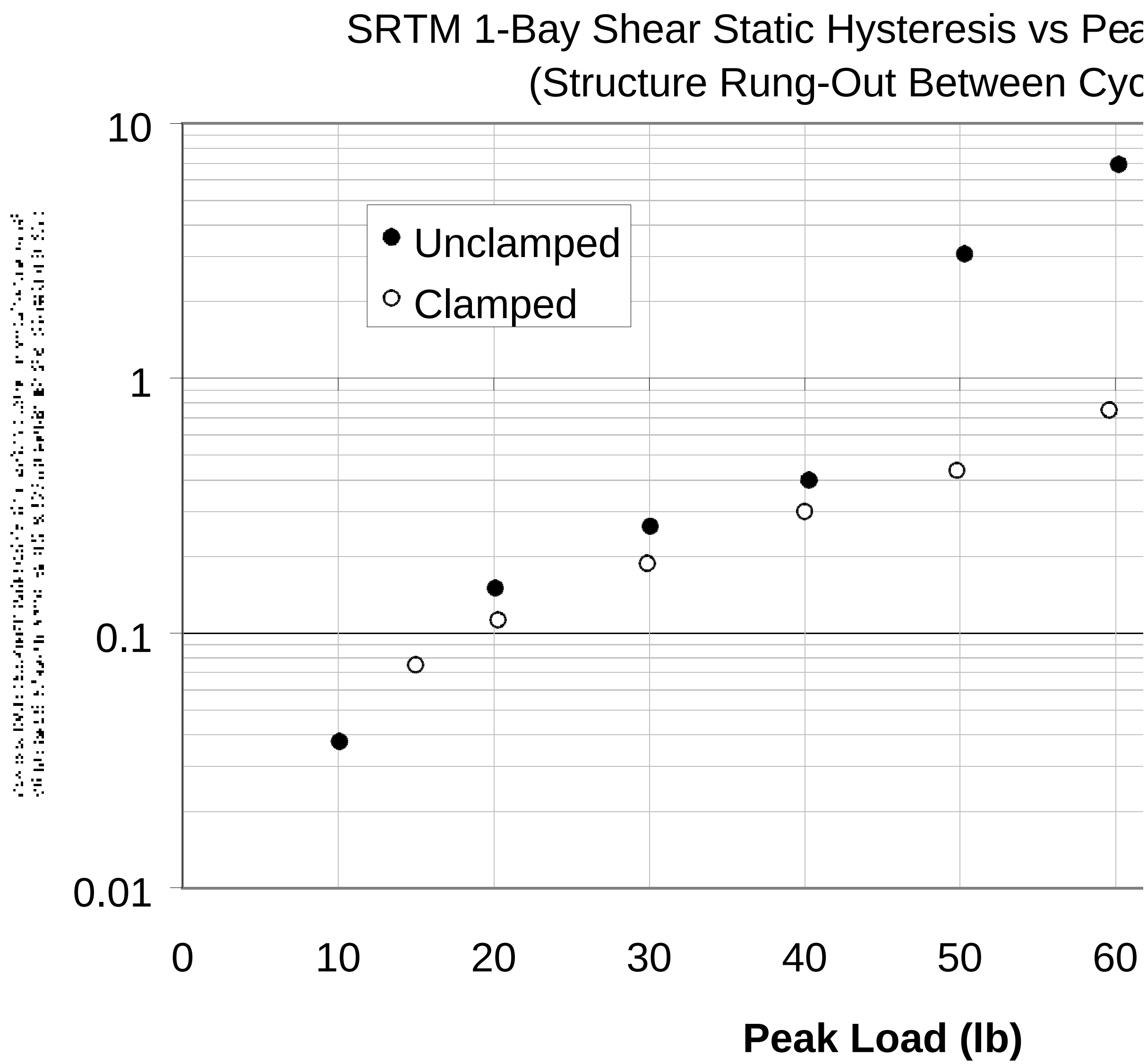

Figure 3

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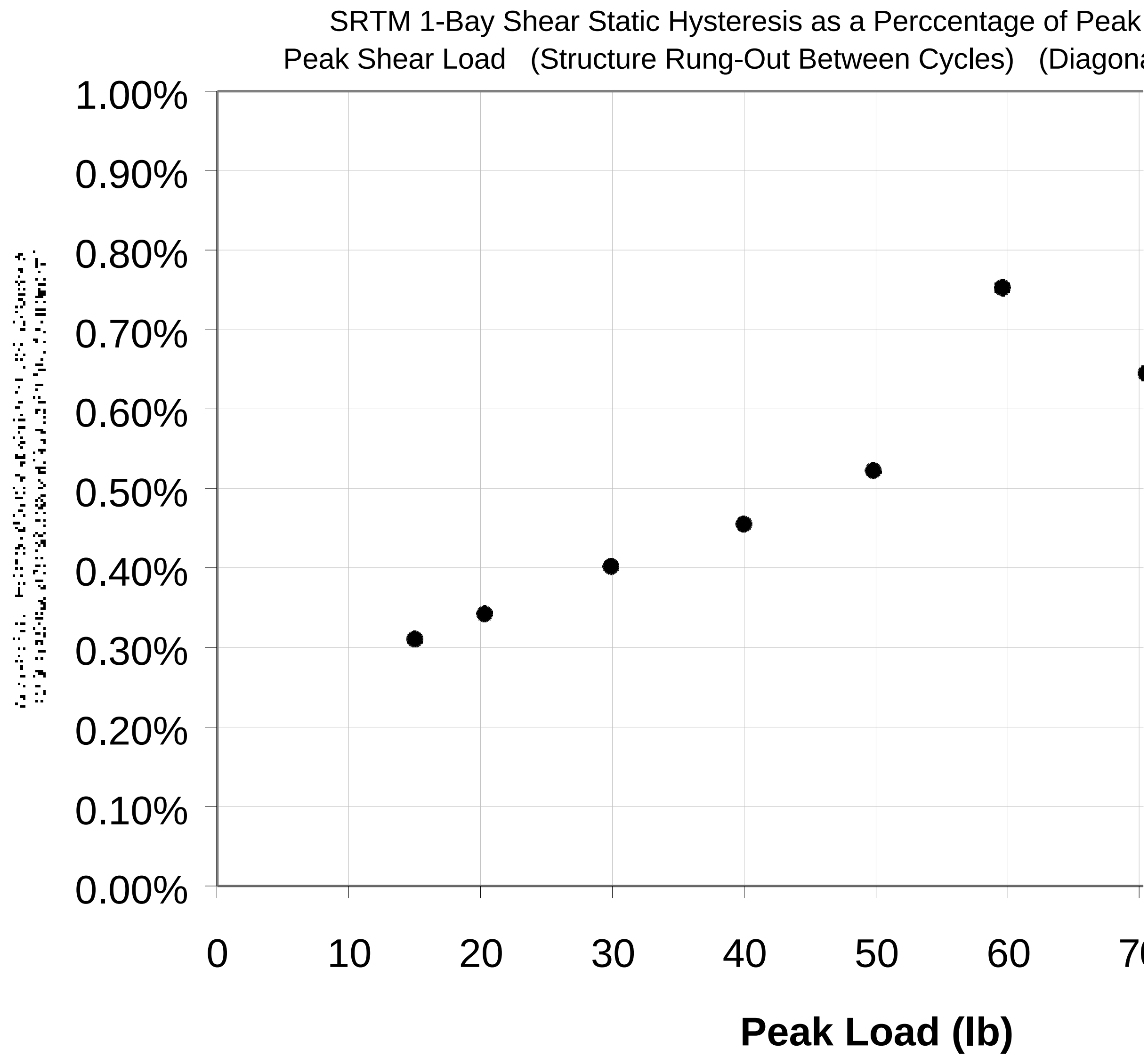

Figure 4

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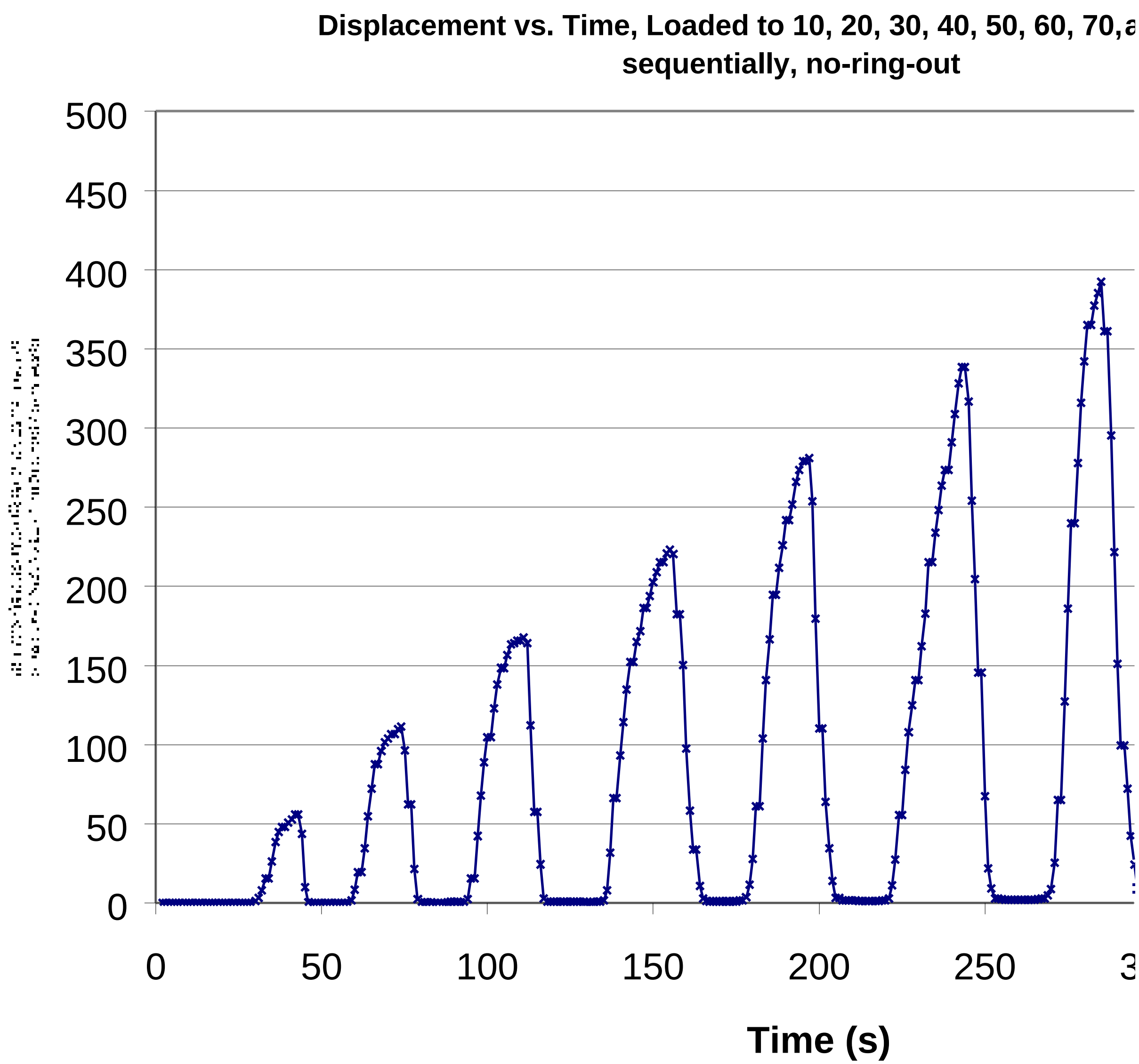

Figure 5

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Displacement vs. Time, Loaded to 10, 20, 30, 40, 50, 60, 70, sequentially, no-ring-out

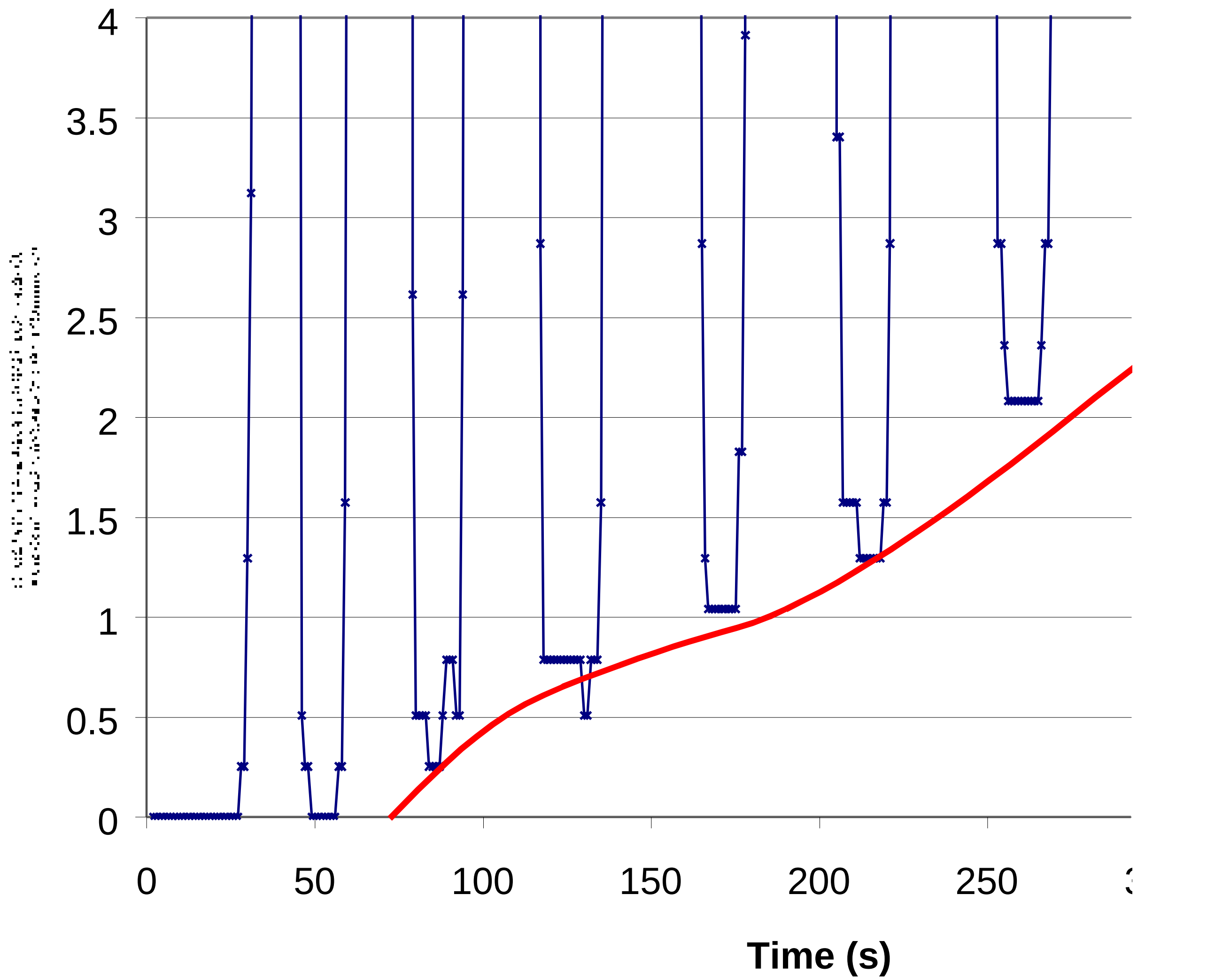

Figure 6

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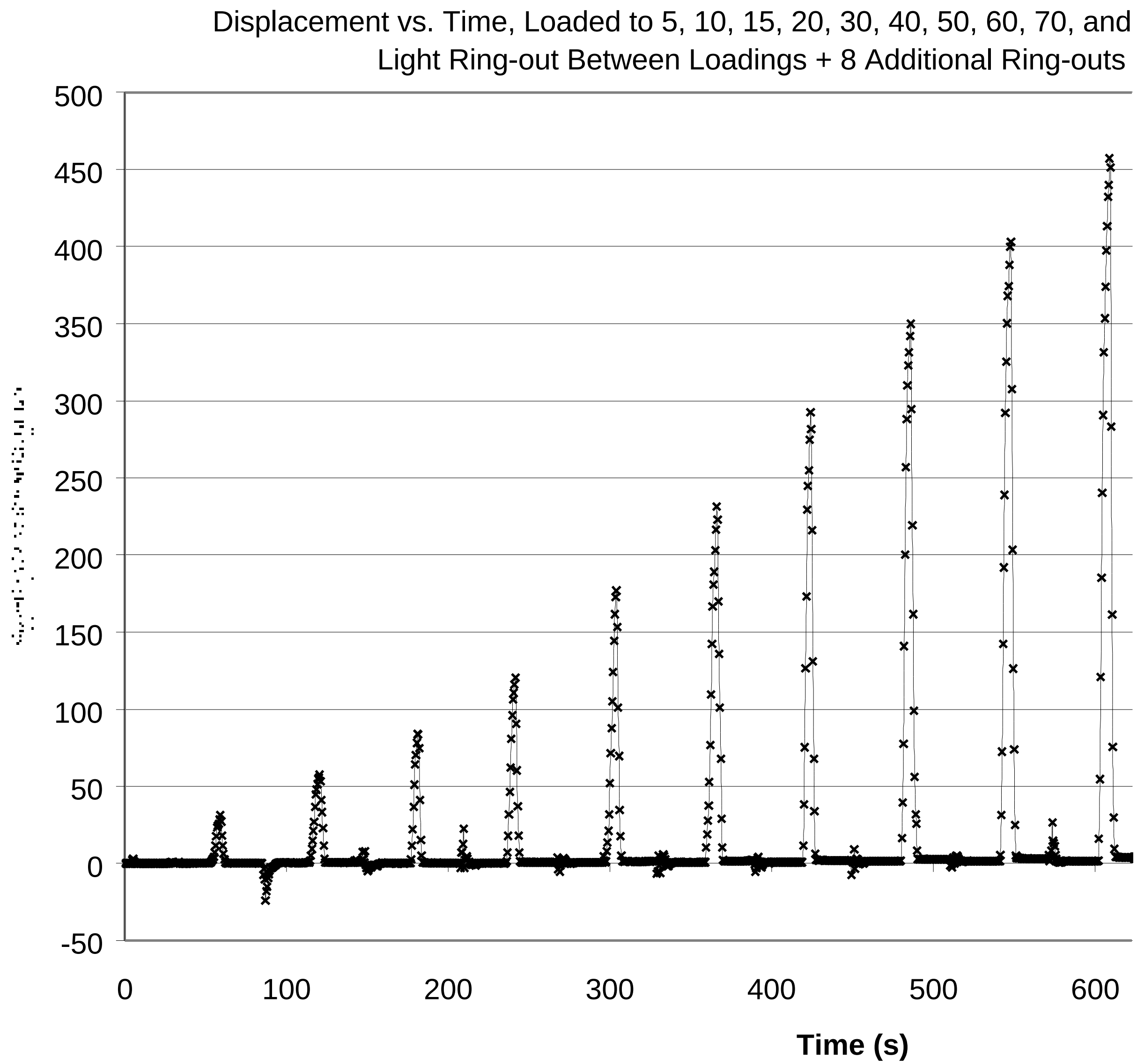

Figure 7

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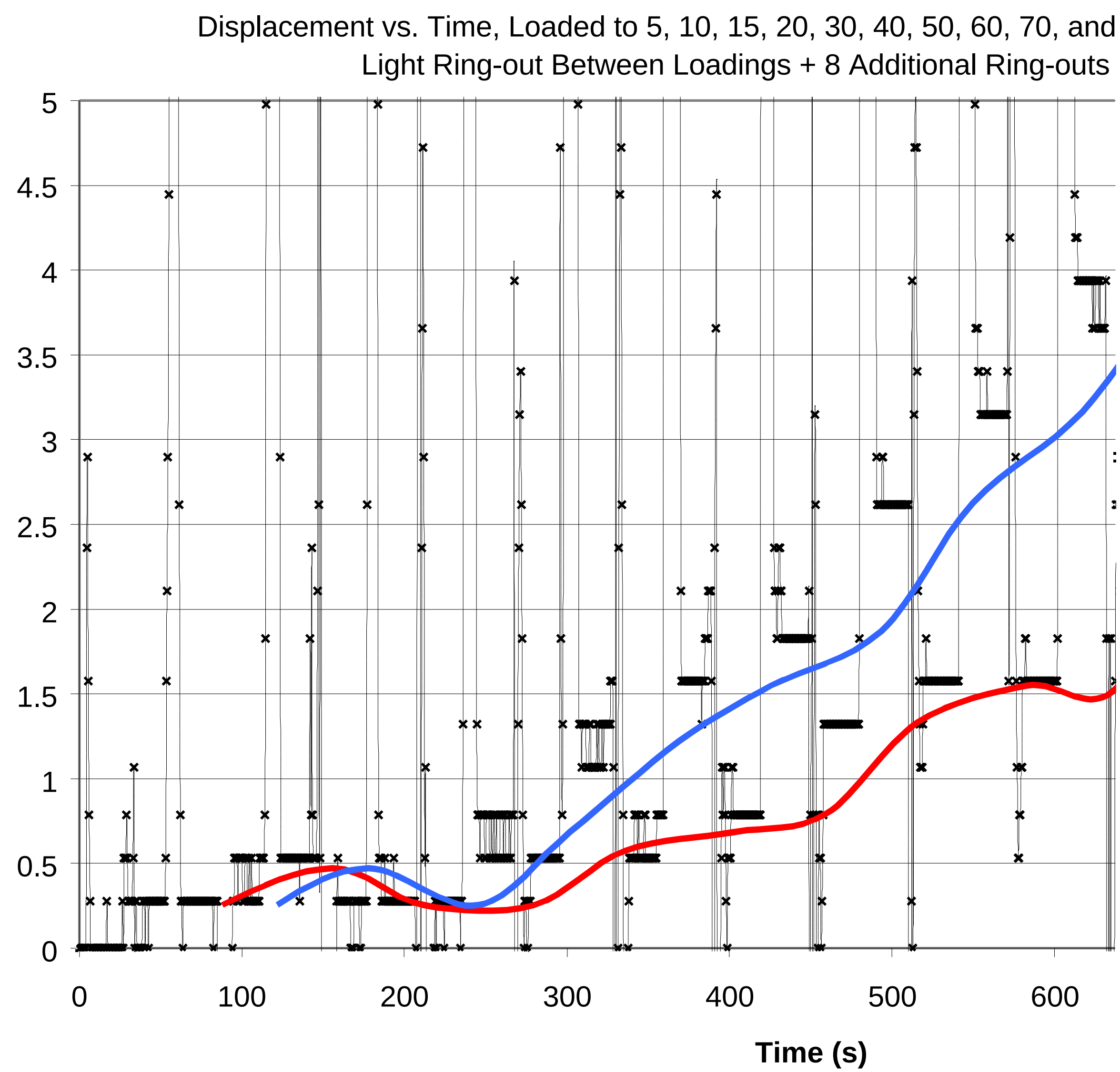

Figure 8

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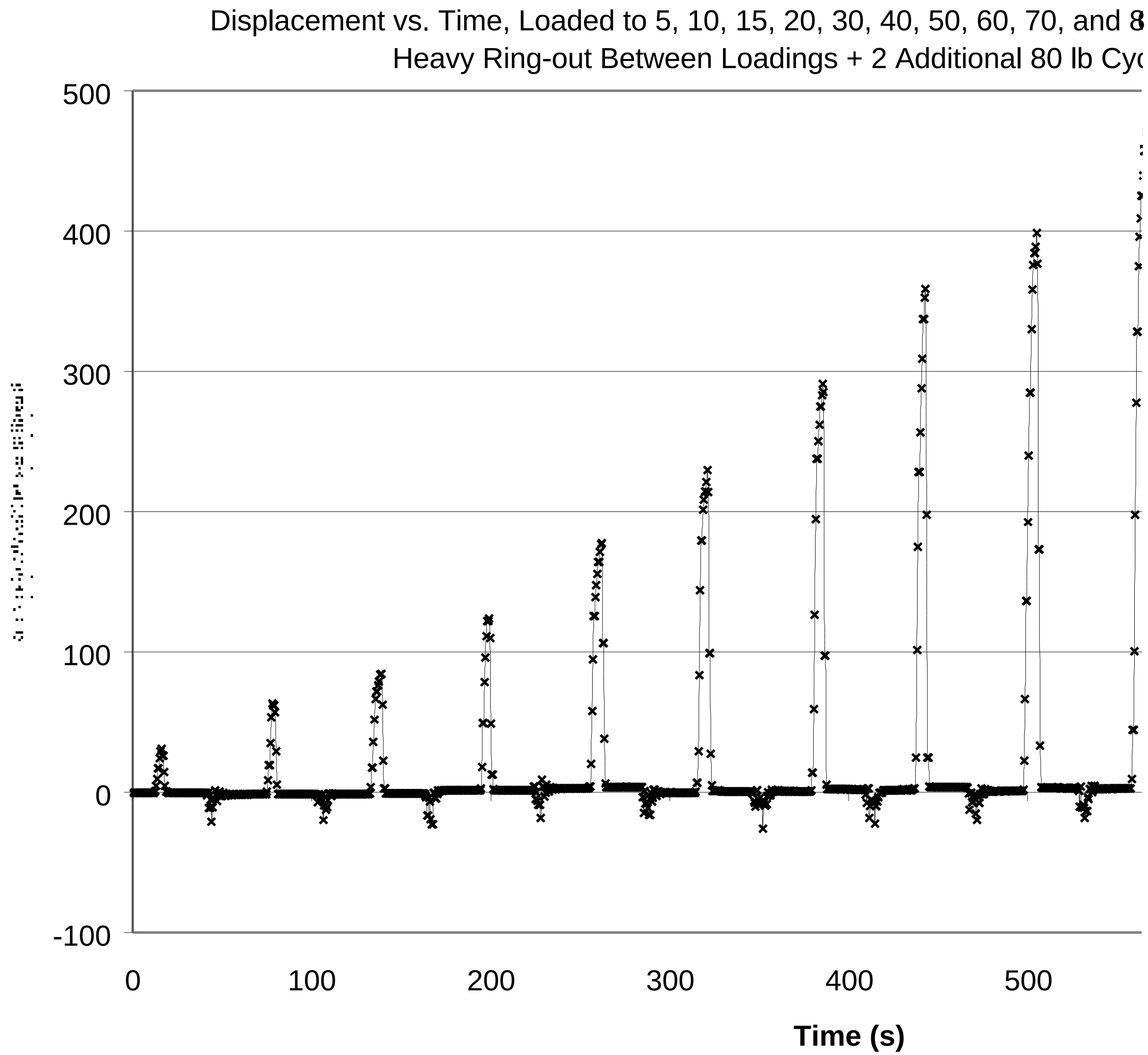

Figure 9

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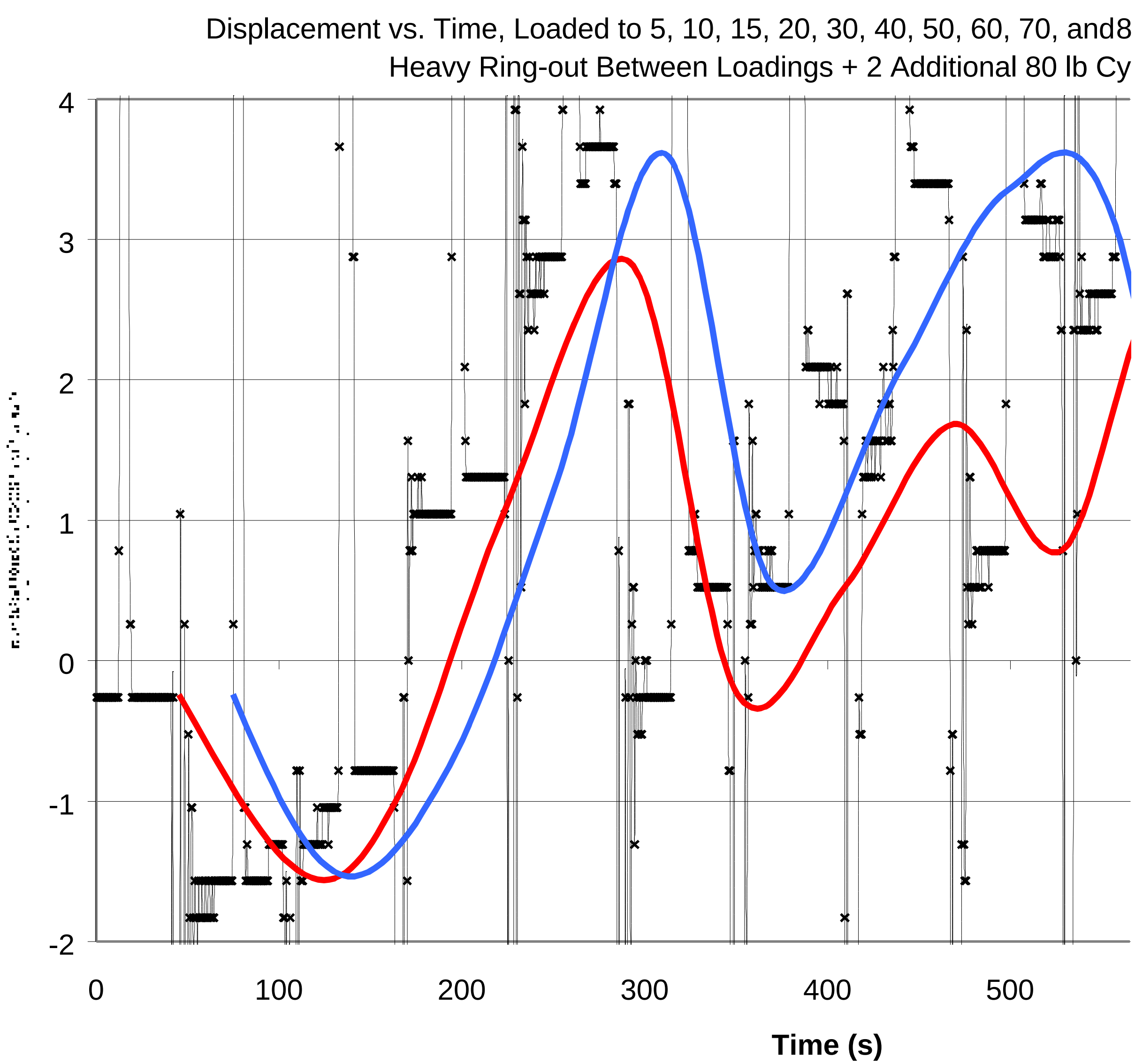

Figure 10

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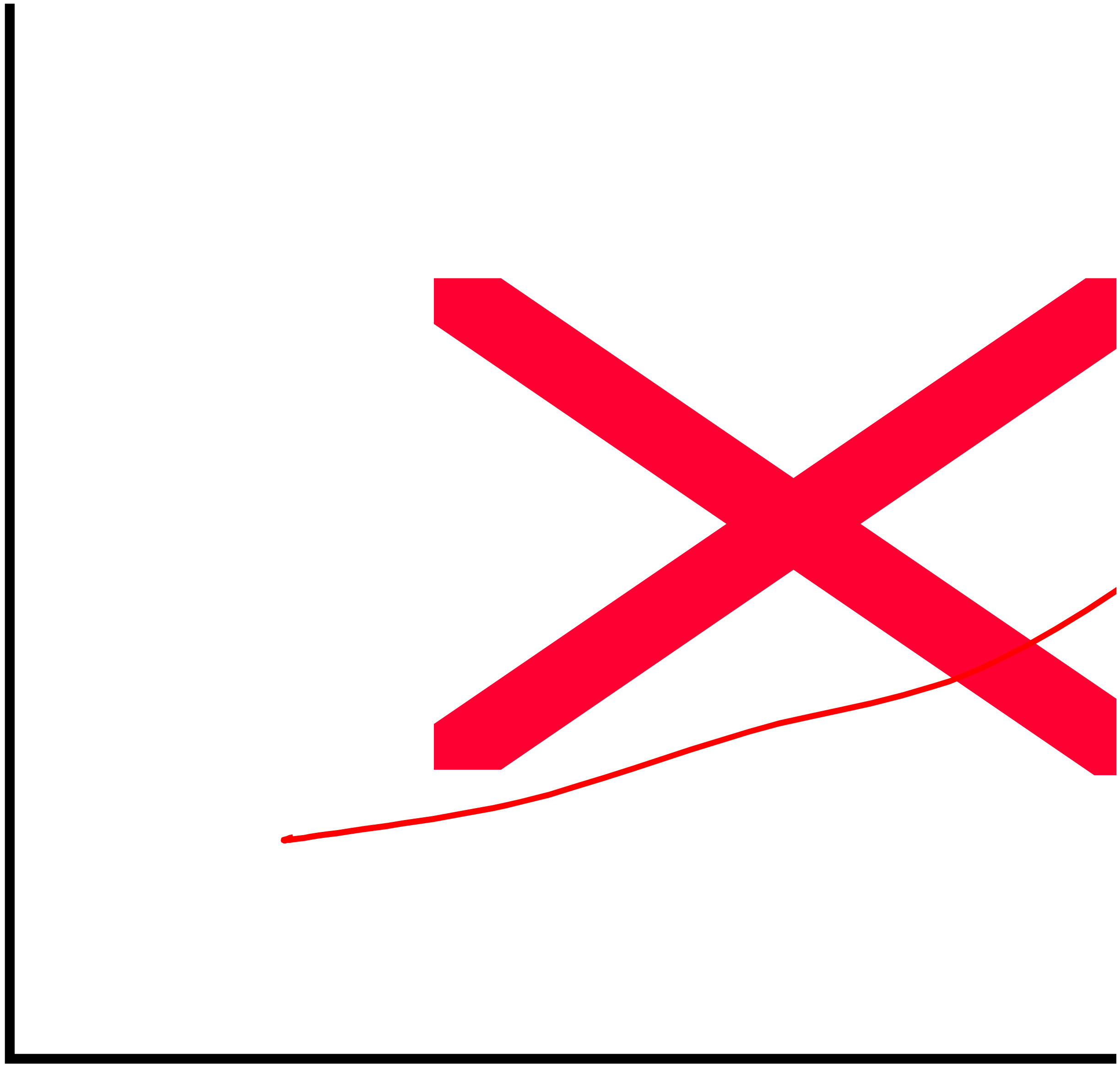

Figure 11

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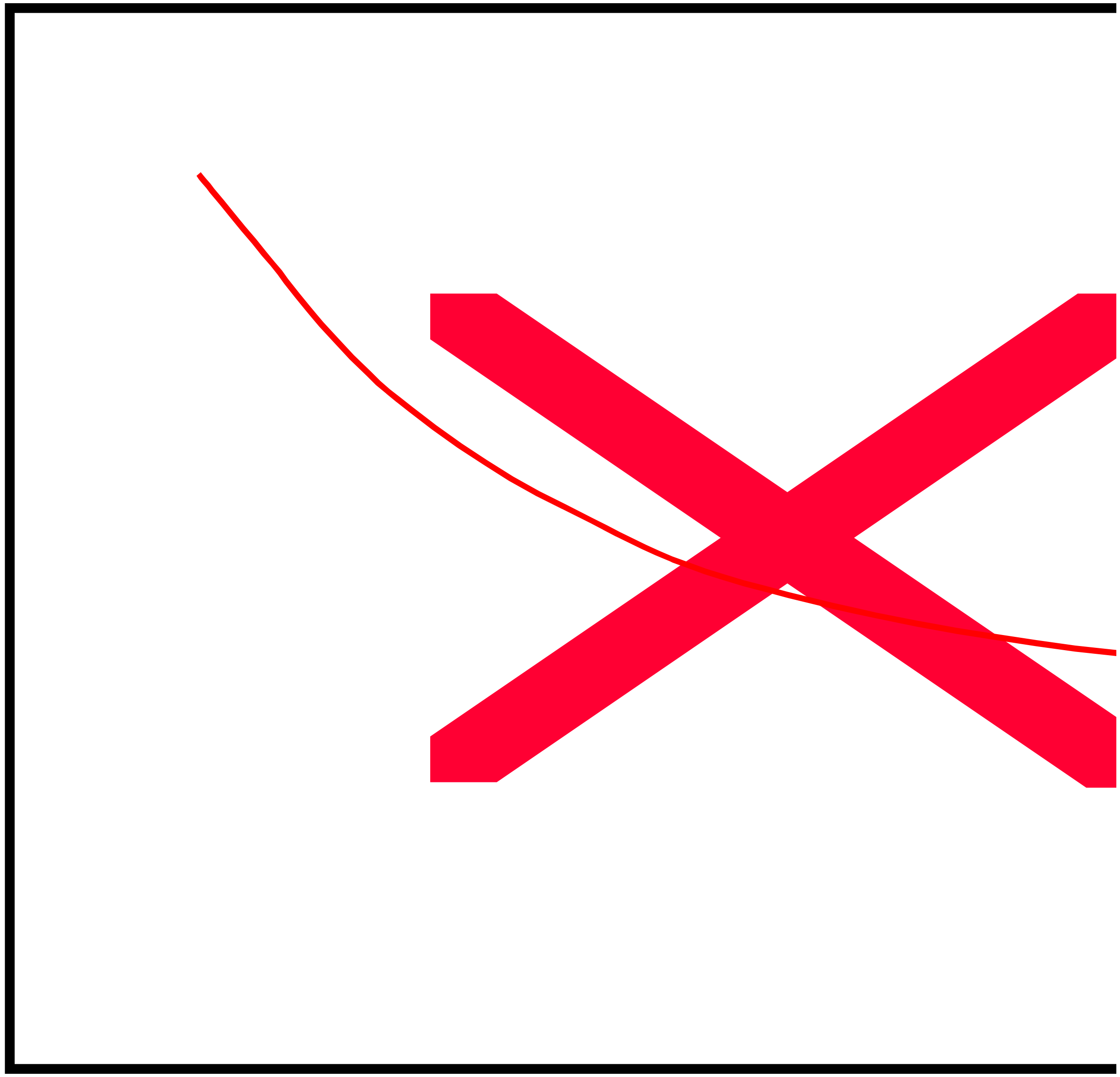

Figure 12

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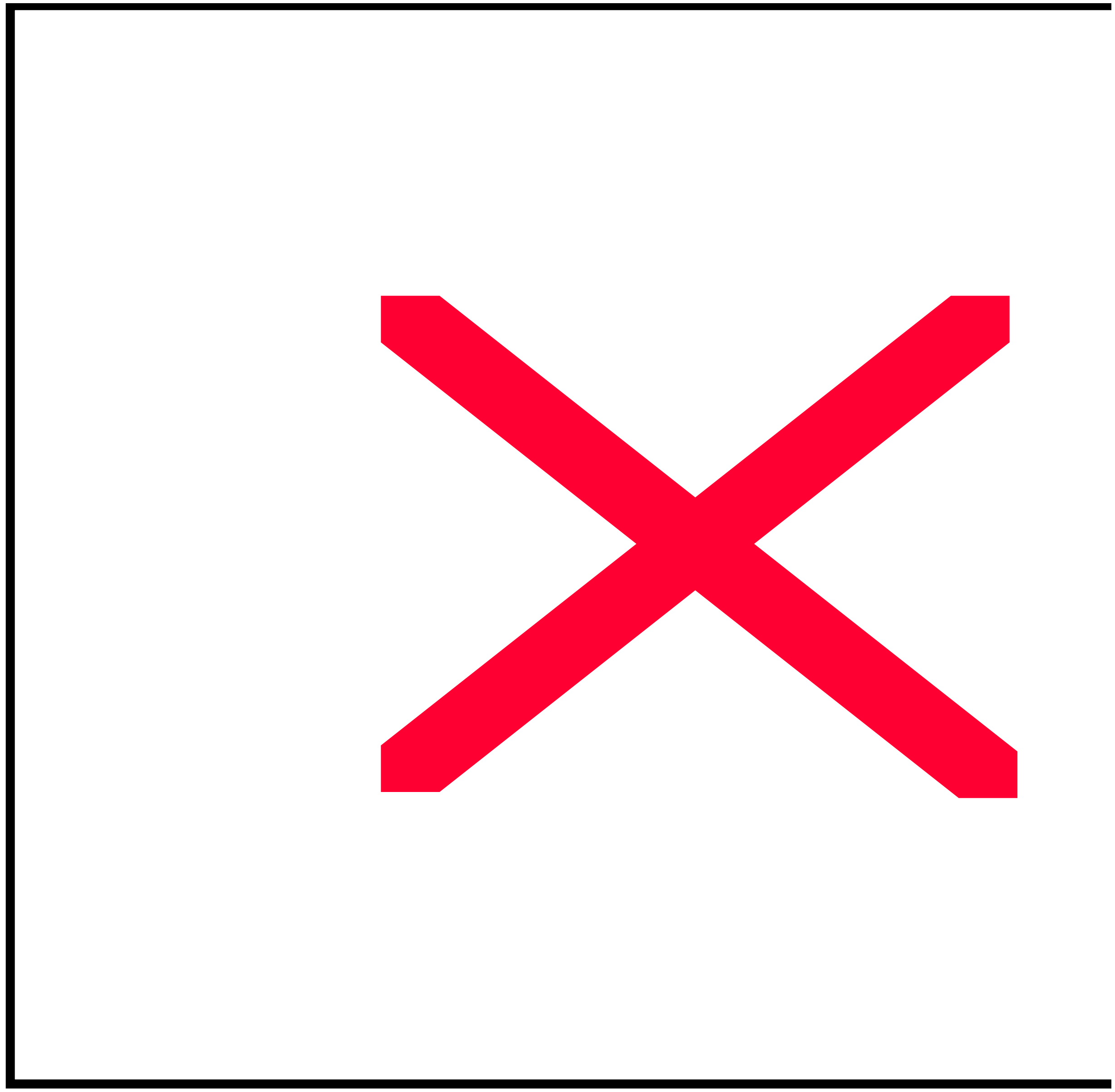

Figure 13

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CONCLUSIONS

- At peak operational (during mapping) lateral tip loads (1.2 lb), static shear hysteresis on SRTM (86 bays; ~3μm) is roughly 0.01% of the required deployment repeatability window and 0.001% of the on-orbit response budget. (unclamped flight configuration)
- At peak non-operational (orbital maintenance) lateral tip loads (15 lb), static shear hysteresis on SRTM (86 bays; ~30μm) is roughly 0.1% of the required deployment repeatability window and 0.01% of the on-orbit response budget. (unclamped flight configuration)
- Even at excessively high lateral loads (45 lb), static shear hysteresis on SRTM (86 bays; ~300μm) would be roughly 1% of the required deployment repeatability window and 0.1% of the on-orbit response budget. (unclamped flight configuration)

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MORE CONCLUSIONS

- The SRTM latch design provides low hysteresis up to shear loads that are roughly equal to half of the cable tension at unlatching (40 lb vs. 72 lb) (unclamped flight configuration).
- Static torsion hysteresis is governed by the same portions of the structure and should be investigated.
- ADAM non-linearities in shear are repeatable, and can be quantified and modeled from the results presented herein.

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NOTES

The basic test approach was to rigidly mount the deployed bay to the concrete floor, apply shear loads, and make corresponding shear displacement measurements. Loads from 1 to 80 lb were applied. A load cell and LVDT were used to make all measurements. For the most part, the displacements of interest were not those that occurred during the applied loads, but the difference between rest positions of the structure, before and after loading. This difference is loosely defined as static hysteresis.

On most occasions, the structure was “rung-out” between load cycles to attempt to settle the structure so each test could be treated as independent. Ring-out was done by impacting the plate attached to the top of the structure several times with a softheaded hammer. Impacts were usually mage at the corners of the structure, at 45 degrees to the loading direction. A qualitative attempt was made to randomize the impacts. No attempt was made to quantify the magnitude of the impacts, except for a relative comparison presented in the charts. The ring-out method was found to be far from ideal, but satisfactory for our purposes.

The goal was to quantify changes in static hysteresis as a function of applied load. This was done in several different ways, under different circumstances. A dynamic ring-down, or “twang test” was also performed to assess any change in damping as a function of amplitude. The test results are presented in the 13 figures.

Figure 1: Static Hysteresis vs Peak Shear Load – static hysteresis was found to increase with shear load. Initial tests (unclamped) revealed two separate regimes of displacement as a function of load. It was hypothesized that the higher displacements occurring at loads greater than 40 lb were due to movement of the ball in the diagonal latch. Subsequent re-tests with the latches “clamped” eliminated this second regime of displacement. It is thought that clamping the latches served to increase the internal preload beyond that already being provided by the latch springs, pushing that second regime out to the right, beyond the limits of the test. This implies a correlation between latch spring preload and useful on-orbit load range for a particular ADAM structure. The peak SRTM on-orbit shear load is roughly 15 lb.

Figure 2: Cumulative Displacement – a time history of shear displacement and applied load shows the general trend of the structure when loaded sequentially in the same direction, referenced back to the original position, rather than treating each cycle independently, as was done in Figure 1.

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MORE NOTES

Figure 3: Shear Data Presented as an Angle – This method of presenting the data is more consistent with current precision and stability requirements for programs such as the Wide Swath Ocean Altimeter (WSOA) and the Advanced Solar Coronal Explorer (ASCE). The angle is the arctangent of the displacement over the length of one bay. This provides a number that is independent of the number of bays in a mast. Therefore, this chart can be used to estimate the shear hysteresis performance of any size or length ADAM of the same basic design.

Figure 4: % of Peak Displacement – This chart shows that the hysteresis grows faster than the applied load.

Figures 5 & 6: Time History – No Ring-out – These figures show a continuous time history of lateral displacements at increasing loads. The two charts present the same data set. Figure 5 shows the whole displacement scale to indicate the peaks. Figure 6 is a close-up of the residual displacements.

Figures 7-10: Time History – With Ring-out – These figures show two continuous time histories of lateral displacements at increasing loads. Figures 7 (full-scale) and 8 (close-up) present the same data set. Figures 9 (full-scale) and 10 (close-up) present the same data set. The difference between the two sets is the relative magnitude of the ring-out.

Figure 11: Low Loads – This figure presents data similar to Figure 6, but for low loads (1-5 lb). This load level is still 1-2 orders of magnitude higher than those experienced on reaction wheel controlled science platforms.

Figures 12 & 13: Ring Down Displacement and Damping – Figure 12 displays the free decay from the release of a 75 lb lateral load. The overlaid damping coefficient is calculated from the log decrement using various averaging and filtering methods. The approximately _ Hz ripple seen in the displacement data is thought to be some type of signal interference, or a cross-talk frequency between the bay shear mode and some other mode that may have been excited. Figure 13 is a close-up of a portion of the ring-down showing the resolution of the data.